

SPECIFICATION

PROCESS FOR PRODUCTION OF PHENOLIC NOVOLAK

5 TECHNICAL FIELD

The present invention relates to a process for production of a phenolic novolak, and more particularly to a production process capable of producing a phenolic novolak having the contents of a
10 monomeric phenol and a dimeric phenol and a degree of dispersion (Mw/Mn) controlled in high yield.

BACKGROUND ART

Conventionally, the phenolic novolak is generally
15 produced by switching from a homogeneous reaction of a phenol and an aldehyde in the presence of an acid catalyst to a heterogeneous reaction starting from an emulsification phenomenon, further pursuing the reaction, checking the production of an initial
20 condensate having a desired degree of condensation before terminating the condensation reaction, and conducting the reduction of low-molecular-weight components and dehydration in the initial condensate by vacuum concentration. And, the phenolic novolak
25 has relatively favorable electric properties and also excels in heat resistance and flame retardance. Therefore, it is extensively used as a base resin for an epoxy resin which is used for, for example, electric and electronic materials, semiconductor
30 sealers and the like required to have remarkable

electric properties or a curing agent for epoxy resins,
a base resin for a photoresist to be used for LCDs and
semiconductors and also used as a binder for laminated
plates, forming materials, mold materials, and the
5 like.

But, when the conventional phenolic novolak was
used for the electric and electronic materials,
semiconductor sealers or the like, the resin contained
a monomeric phenol and a dimeric phenol in a large
10 amount, so that there were various problems such as
environmental pollution because of volatilization of
the monomeric phenol involving an odor, a degradation
in production efficiency because of falling of the
dimeric phenol, which were sublimated to deposit on
15 the side and ceiling of the apparatus when a
photoresist coated on a substrate such as glass for
liquid crystal display was baked, onto the substrate,
and a degradation in crosslinking density of a cured
resin substance affecting on the heat resistance, and
20 the like. Because the molecular weight distribution
was broad, there were also disadvantages that the
molten resin had a high viscosity and poor moldability.

Where the phenolic novolak is used as a binder
for castings, it is demanded to decrease phenol
25 monomer contained in the phenolic resin as low as
possible because the phenol monomer applies to the
PRTR law (Pollutant Release and Transfer Register) and
the phenol monomer contained in the binder becomes tar
in a high-temperature atmosphere, resulting in
30 defective casting such as a gas defect. In other

words, as the phenolic resin for the casting binder, a phenolic novolak having properties that a content of monomeric phenol is decreased, a molecular weight is low and the molecular weight distribution is narrow is demanded.

For example, as a method for reduction of the monomeric phenol and dimeric phenol contained in the above phenolic resin, there is proposed a method of removing low-molecular weight components by blowing in inert gas or vapor to condense a novolak-based condensate at 150°C to 210°C after the condensation reaction is completed (Japanese Patent Publication No. Hei 7-91352). This method has a reliable effect of decreasing the monomeric phenol and dimeric phenol but has a disadvantage that their removal lowers the yield of the resin.

The present invention has been made in view of the above circumstances and provides a process for production capable of producing a phenolic novolak with the contents of a monomeric phenol and a dimeric phenol and a degree of dispersion (Mw/Mn) controlled in high yield by reacting a phenol and an aldehyde in the presence of a phosphoric acid and a reaction cosolvent.

SUMMARY OF THE INVENTION

The process for production of a phenolic novolak of the present invention comprises a step of conducting a heterogeneous reaction of a phenol with an aldehyde in the presence of a phosphoric acid and

an unreactive oxygen-containing organic solvent as a reaction cosolvent.

Here, the compounding amount of the phosphoric acid is preferably 5 parts by mass or more per 100 parts by mass of the phenol and more preferably 25 parts by mass or more, the compounding amount of the reaction cosolvent is preferably 5 parts by mass or more to 100 parts by mass of the phenol, and more preferably 10 to 200 parts by mass, and a ratio of the phenol and the aldehyde is preferably 0.40 to 1.0 mol of the aldehyde per mol of the phenol.

As the reaction cosolvent, it is preferable to use at least one selected from the group consisting of an alcohol, a polyalcohol-based ether, a cyclic ether, a polyalcohol-based ester, a ketone and a sulfoxide.

And, it is also preferable to have a surface active agent in the step of conducting the heterogeneous reaction.

It is also preferable to conduct the step of the heterogeneous reaction under pressure of 0.03 to 1.50 MPa.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a gel permeation chromatography (hereinafter might be referred to as the "GPC") chart of a phenolic novolak (hereinafter might be referred to as the "novolak resin") obtained in Example 1; Fig. 2 is a GPC chart of the novolak resin obtained in Example 14; Fig. 3 is a GPC chart of the novolak resin obtained in Example 20; Fig. 4 is a GPC chart of the

novolak resin obtained in Example 21; Fig. 5 is a GPC
chart of the novolak resin obtained in Example 26; Fig.
6 is a GPC chart of the novolak resin obtained in
Example 36; Fig. 7 is a GPC chart of the novolak resin
5 at the completion of condensation obtained in Example
41; Fig. 8 is a GPC chart of the novolak resin at the
completion of condensation obtained in Example 55; Fig.
9 is a GPC chart of the novolak resin at the
completion of condensation obtained in Example 61; Fig.
10 10 is a GPC chart of the novolak resin obtained in
Comparative Example 1; Fig. 11 is a GPC chart of the
novolak resin obtained in Comparative Example 6; Fig.
12 is a GPC chart of the novolak resin obtained in
Comparative Example 8 at the completion of
15 condensation; Fig. 13 is a GPC chart of the novolak
resin at the completion of condensation obtained in
Comparative Example 9; and Fig. 14 is a rheometer
measurement chart of an epoxy resin. In the drawings,
1 denotes a peak corresponding to a monomeric phenol
20 and 2 denotes a peak corresponding to a dimeric phenol.

BEST MODE FOR CARRYING OUT THE INVENTION

A process for production of the phenolic novolak
according to the present invention has a step which
25 requires a phenol and an aldehyde as raw materials, a
phosphoric acid as an acid catalyst, and an unreactive
oxygen-containing organic solvent as a reaction
cosolvent, stirs to mix them in a two-phase separated
state by, for example, mechanical stirring, ultrasonic
30 wave or the like, and pursues a reaction between the

phenol and the aldehyde in a cloudy heterogeneous reaction system with the two phases (organic phase and water phase) mixed to synthesize a condensate (resin).

Then, for example, a water-insoluble organic solvent (e.g., methyl ethyl ketone, methyl isobutyl ketone or the like) is added and mixed to dissolve the condensate, the stirring for mixing is stopped, and the mixture is left standing to separate into the organic phase (organic solvent phase) and the water phase (aqueous phosphoric acid solution phase). Then, the water phase is removed for recovering, while the organic phase is washed with hot water and/or neutralized and recovered by distillation. Thus, the novolak resin can be produced.

The process for production according to the invention employs a phase separation reaction, so that stirring efficiency is quite important, and it is desirable to miniaturize both phases in the reaction system to increase the surface area of the interface as large as possible in view of the reaction efficiency, and the conversion of the monomeric phenol into the resin is promoted.

Examples of the phenol used as the raw material are phenol, orthocresol, metacresol, paracresol, xylenol, a bisphenol, an orthosubstituted phenol having a hydrocarbon radical containing 3 or more carbon atoms, preferably 3 to 10 carbon atoms, in the ortho-position, a parasubstituted phenol having a hydrocarbon radical containing 3 or more carbon atoms, preferably 3 to 18 carbon atoms, in the para-position,

and the like.

Here, examples of the bisphenol are bisphenol A, bisphenol F, bis(2-methyl phenol)A, bis(2-methyl phenol)F, bisphenol S, bisphenol E, bisphenol Z and
5 the like.

Examples of the orthosubstituted phenol are 2-propylphenol, 2-isopropylphenol, 2-sec-butylphenol, 2-tert-butylphenol, 2-phenylphenol, 2-cyclohexylphenol, 2-nonyl phenol, 2-naphthyl phenol and the like.
10 Especially, 2-phenylphenol, 2-tert-butylphenol, 2-cyclohexylphenol are suitably used in the field of the epoxy resin.

Examples of the parasubstituted phenol are 4-propylphenol, 4-isopropylphenol, 4-sec-butylphenol, 4-tert-butylphenol, 4-phenylphenol, 4-cyclohexylphenol, 4-nonyl phenol, 4-naphthyl phenol, 4-dodecylphenol, 4-octadecylphenol and the like.
15

Meanwhile, examples of the aldehyde are formic aldehyde, formalin, paraformaldehyde, trioxane, acetic
20 aldehyde, paraaldehyde, propionaldehyde and the like. Among them, the paraformaldehyde is desirable in view of a reaction velocity.

Those raw materials are not limited to the exemplified ones and can be used alone or as a
25 combination of two or more of them.

A compounding mole ratio (F/P) of the aldehyde (F) and the phenol (P) is 0.33 or more, preferably 0.41 to 1.0, and more preferably 0.50 to 0.90. If it is less than 0.33, there is a possibility that the
30 effect of improving the yield is degraded.

The phosphoric acid used as the acid catalyst plays an important role to form a place for a phase separation reaction with the phenol in the presence of water. Preferably, an aqueous solution type, e.g.,
5 89% by mass phosphoric acid or 75% by mass phosphoric acid, is used but, for example, polyphosphoric acid or anhydrous phosphoric acid may be used if necessary.

The compounding amount of the phosphoric acid has a considerable effect on the control of the phase
10 separation effect and it is generally 5 parts by mass or more, preferably 25 parts by mass or more, and more preferably 50 to 100 parts by mass, per 100 parts by mass of the phenol. Where 70 parts by mass or more of phosphoric acid is used, it is desirable to secure
15 safety by suppressing heat generation in the early stage of reaction by split-charging to the reaction system.

The unreactive oxygen-containing organic solvent as the reaction cosolvent plays a very important role
20 to promote the phase separation reaction. As the reaction cosolvent, it is desirable to use at least one member selected from a group consisting of an alcohol, a polyalcohol-based ether, a cyclic ether, a polyalcohol-based ester, a ketone and a sulfoxide.

25 Examples of the alcohol are monohydric alcohol such as methanol, ethanol or propanol, dihydric alcohol such as butanediol, pentanediol, hexanediol, ethylene glycol, propylene glycol, trimethylene glycol, diethylene glycol, dipropylene glycol, triethylene
30 glycol, tripropylene glycol or polyethylene glycol,

trihydric alcohol such as glycerin, and the like.

Examples of the polyalcohol-based ether are ethylene glycol monomethyl ether, ethylene glycol monoethyl ether, ethylene glycol monopropyl ether,
5 ethylene glycol monobutyl ether, ethylene glycol monopentyl ether, ethylene glycol dimethyl ether, ethylene glycol ethylmethyl ether, ethylene glycol ether and the like.

Examples of the cyclic ether are 1,3-dioxane,
10 1,4-dioxane and the like, examples of the polyalcohol-based ether are glycol esters such as ethylene glycol acetate, examples of the ketones are acetone, methyl ethyl ketone, methyl isobutyl ketone and the like, and examples of the sulfoxide are dimethyl sulfoxide,
15 diethyl sulfoxide and the like.

Among them, ethylene glycol monomethyl ether, polyethylene glycol and 1,4-dioxane are particularly desirable.

The reaction cosolvents are not limited to the
20 above-described examples but solid types can also be used if they have the above-described properties and are in a state of liquid at the time of the reaction. And, they can be used alone or as a combination of two or more.

25 The reaction cosolvent is not limited to a particular blending amount but used in 5 parts by mass or more, and preferably 10 to 200 parts by mass, per 100 parts by mass of phenol.

And, by additional used of a surface active agent
30 in the heterogeneous reaction step, the phase

separation reaction is promoted, the reaction time can be reduced, and the yield can also be improved.

Examples of the surface active agent are anionic surface active agents such as soap, alpha olefin sulfonate, alkylbenzene sulfonic acid and its salt, alkyl sulfate, alkyl ether sulfate, phenyl ether ester salt, polyoxyethylene alkylether sulfate, ether sulfonate and ether carboxylate; nonionic surface active agents such as polyoxyethylene alkyl phenyl ether, polyoxyalkylene alkylether, polyoxyethylene styrenated phenol ether, polyoxyethylene alkylamino ether, polyethylene glycol aliphatic ester, aliphatic monoglyceride, sorbitan aliphatic ester, pentaerythritol aliphatic ester, polyoxyethylene polypropylene glycol and aliphatic alkylol amide; and cationic surface active agents such as monoalkyl ammonium chloride, dialkyl ammonium chloride and an amino-acid salt.

The compounding amount of the surface active agent is not limited to a particular amount but 0.5 part or more per 100 parts by mass of a phenol, and preferably 1 to 10 parts by mass.

An amount of water in the reaction system has an effect on a phase separation effect and a production efficiency but is generally 40% or less according to the mass standard. If the amount of water exceeds 40%, there is a possibility that the production efficiency decreases.

A reaction temperature between the phenol and the aldehyde is variable depending on types of phenols and reaction conditions, and not limited particularly but

generally 40°C or more, preferably 80°C to a reflux temperature, and more preferably a reflux temperature.

If the reaction temperature is less than 40°C, the reaction time becomes very long, and the phenol

5 monomer cannot be reduced easily. The reaction time is variable depending on the reaction temperature, blending amount of phosphoric acid, a water content in the reaction system and the like but generally about 1 to 10 hours.

10 As a reaction environment, it is general to have normal pressure, but the reaction may be made under pressure or under a reduced pressure if the heterogeneous reaction which is a feature of the present invention is maintained. Particularly, under
15 pressure of 0.03 to 1.50 MPa, a reaction velocity can be increased, and a low-boiling solvent such as methanol can be used as a reaction cosolvent.

When the process for production of the present invention is used, the following phenolic novolaks are
20 generally obtained in the compounding mole ratio (F/P) of an aldehyde (F) and a phenol (P) though variable to some extent depending on types of phenols.

When the compounding mole ratio (F/P) is 0.80 mol or more, and preferably in a range of 0.80 mol or more
25 and 1.00 mol or less, phenolic novolak can be produced in high yield in that a total content of a monomeric phenol and a dimeric phenol is 10% or less, and preferably 5% or less according to the measurement made by the GPC area method, and the degree of
30 dispersion (M_w/M_n) of the weight-average molecular

weight (Mw) and the number-average molecular weight (Mn) is 1.1 to 3.0, preferably 1.2 to 2.0, according to GPC measurement.

When the compounding mole ratio (F/P) is in a
5 range of 0.33 or more and less than 0.80, phenolic novolak can be produced in high yield in that in that a monomeric phenol content is 3% or less, preferably 1% or less, and a dimeric phenol content is 5% to 95%, preferably 10% to 90% when measured by the GPC area
10 method, and the degree of dispersion (Mw/Mn) of the weight-average molecular weight (Mw) and the number-average molecular weight (Mn) is 1.05 to 1.8, preferably 1.1 to 1.7, according to GPC measurement.

It is not necessarily clear why the novolak resin
15 is obtained in good yield with the contents of the monomeric phenol and dimeric phenol and the degree of dispersion (Mw/Mn) controlled according to the process for production of the invention but it is presumed as follows.

20 In the heterogeneous reaction system in a cloudy state that the organic phase having the phenol as the main ingredient and the water phase having the phosphoric acid, the aldehyde and a reaction cosolvent as the main ingredients are mixed, the phenol in the
25 organic phase dissolves into the water phase by the dissolution promoting action of the reaction cosolvent and reacts with the aldehyde under the catalyzing conditions of the phosphoric acid to grow as a condensate (resin), which cannot coexist in the water
30 phase and moves to the organic phase having the

condensate dissolving power, and the further growth of the condensate is suppressed or stopped, so that it is prevented from being of high molecular weight. Thus, the process of the invention applies a two-liquid
5 phase interface reaction having a mechanism of suppressing the resinification of the phenol in the water phase and the resin from being of high molecular weight in the organic phase, so that it is assumed that the resin having the contents of the monomeric
10 phenol and dimeric phenol and a degree of dispersion (Mw/Mn) controlled is produced at the end of the condensation reaction, and the yield is considerably improved.

It is considered from the above that the setting
15 of the compounding ratio of the reaction raw materials and the compounding amount of phosphoric acid and reaction cosolvent is most significant but water and reaction temperatures essential for the phase separation related to the above are also important to
20 efficiently develop the phase separation effect of the process according to the invention. In other words, the process according to the invention is presumed that the novolak resin having the contents of the monomeric phenol and the dimeric phenol and the degree
25 of dispersion (Mw/Mn) controlled by setting the appropriate reaction conditions according to the above-described presumed reasons can be produced in high yield.

[Examples]

Then, the present invention will be described in further detail in examples but not limited to such examples. The properties of the produced novolak resin were measured by the following testing methods.

(1) Degree of dispersion

Weight-average molecular weight (M_w) and number-average molecular weight (M_n) in terms of the standard polystyrene calibration were determined by Tosoh Corporation's gel permeation chromatography SC-8020 series build-up system (column: G2000Hx1+G4000Hx1, detector: UV 254 nm, carrier: tetrahydrofuran 1 ml/min, column temperature: 38°C), and a degree of dispersion (M_w/M_n) was calculated.

(2) Contents (%) of monomeric phenol and dimeric phenol

Areas of a monomeric phenol and a dimeric phenol to the entire area of the molecular weight distribution were measured by an area method indicating in percentage.

(3) Softening point

According to the Ring-and-Ball method described in JIS-K6910, a ring-and-ball type automatic softening point measuring apparatus ASP-MGK2 produced by MEITECH Company, Ltd. was used for measurement.

(4) Melt viscosity

Measured by a cone plate viscometer (CONE PLATE

VISCOMETER MODEL CV-1 produced by TOA Industry Inc.).

(5) Alkali dissolving velocity ($\text{\AA}/\text{s}$)

Novolak resin was dissolved in ethyl cellosolve acetate, the obtained solution was coated on a silicon wafer by a spin coater, and prebaking was conducted to form a novolak resin film having a thickness of about 15000 \AA . It was immersed in an alkali developing solution (2.38% by mass aqueous tetramethyl ammonium hydroxide solution) at 23°C, time until the film disappeared was measured to determine a thickness dissolved per second ($\text{\AA}/\text{s}$), and it was determined as an alkali dissolving velocity.

(6) Epoxy equivalent (g/eq)

Measured according to JIS-K-7236 (indicator titration method/titration by 0.1N perchloric acid, acetic acid solution).

<Example 1>

Into a reaction vessel provided with a thermometer, a stirring device and a condenser, 193 parts of phenol (P), 57 parts of 92% by mass paraformaldehyde (F) ($F/P=0.85$), 116 parts of 89% by mass phosphoric acid ($53.4\%/P$), 96.5 parts of ethylene glycol ($50\%/P$) were charged and gradually raised to a reflux temperature (98 to 102°C) in a cloudy condition (two-phase mixture) formed by stirring for mixing, and at the same temperature, a condensation reaction was conducted for ten hours,

then the reaction was stopped.

Then, methyl isobutyl ketone was added to dissolve the condensate while stirring for mixing, the stirring for mixing was stopped, the content was moved
5 into a separating flask and left standing to separate into a methyl isobutyl ketone solution layer (upper layer) and an aqueous phosphoric acid solution layer (lower layer). Then, the aqueous phosphoric acid solution layer was removed, the methyl isobutyl ketone
10 solution was washed with water several times to remove phosphoric acid, the content was returned into the reaction vessel, and the methyl isobutyl ketone was completely removed by vacuum distillation to obtain 213.5 parts of the novolak resin (yield 110.6%/P).
15 The yield of the novolak resin was indicated in percentage with respect to the charged amount of phenol (mass standard).

The obtained novolak resin was measured for its properties according to the testing method described
20 above. The results are shown in Table 1. A GPC chart of the obtained novolak resin is shown in Fig. 1.

<Examples 2 to 7>

Novolak resins were obtained in the same manner
25 as in Example 1 except that the reaction conditions were changed as shown in Table 1. The measured results are shown in Table 1. In Table 1, "N.D." indicates no detection.

Table 1

| | | Example | | | | | | |
|---------------------|---|---------|-------|-------|-------|-------|-------|------|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Reaction conditions | Phenol | 193 | 193 | 193 | 193 | 193 | 193 | 193 |
| | 92% Paraform | 57 | 57 | 57 | 57 | — | 47 | 33.5 |
| | 37%Formalin | — | — | — | — | 142 | — | — |
| | Compounding ratio(F/P)(mole ratio) | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.75 | 0.5 |
| | 89% Phosphoric acid solution | 116 | 116 | 116 | 116 | 116 | 116 | 116 |
| | Compounding amount of phosphoric acid (Pure content)(%/P) | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| | Ethylene glycol | 96.5 | — | — | — | — | — | — |
| | 1,4-Dioxane | — | 96.5 | — | — | 96.5 | — | 19.3 |
| | 1,4-Butanediol | — | — | 96.5 | — | — | 38.6 | — |
| | Methanol | — | — | — | 11.4 | — | — | — |
| Properties | Usage (%/P) | 50 | 50 | 50 | 5.9 | 50 | 20 | 10 |
| | Reaction time(hour) | 10 | 10 | 9 | 11.5 | 10 | 7 | 7 |
| | Monomeric phenol(%) | 0.3 | N.D. | N.D. | 0.4 | N.D. | N.D. | N.D. |
| | Dimeric phenol(%) | 3.3 | 2.3 | 3.1 | 1.3 | 4.7 | 16.3 | 50.1 |
| | Number-average molecular weight(Mn) | 755 | 776 | 780 | 688 | 928 | 390 | 378 |
| | Weight-average molecular weight(Mw) | 1227 | 1110 | 1213 | 1035 | 1551 | 548 | 464 |
| | Degree of dispersion (Mw/Mn) | 1.63 | 1.43 | 1.55 | 1.5 | 1.67 | 1.4 | 1.23 |
| | Melt viscosity (Pa·s/150°C) | 3.13 | 2.31 | 3.46 | 3.34 | 2.47 | 0.03 | 0.04 |
| | Softening point(°C) | 107.3 | 108.5 | 113.3 | 111 | 106.9 | 81.4 | 50.1 |
| | Yield(%) | 110.6 | 106.6 | 105.6 | 107.6 | 109.7 | 107.2 | 82.8 |

<Examples 8 to 18>

Novolak resins were obtained in the same manner as in Example 1 except that the reaction conditions
5 were changed as shown in Table 2. The measured results are shown in Table 2. A GPC chart of the novolak resin obtained in Example 14 is shown in Fig. 2.

Table 2

| | | Example | | | | | | | | | | | | | | | |
|--------------------|---|---------|------|------|------|------|------|------|------|------|------|------|--|--|--|--|--|
| | | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | | | | | |
| Reaction materials | Orthocresol | 216 | 216 | 216 | 216 | 216 | 216 | 216 | 216 | 216 | 216 | 216 | | | | | |
| | 92% Paraform | — | — | — | — | — | — | 49 | 49 | 49 | 49 | 49 | | | | | |
| | 37%Formalin | 130 | 130 | 130 | 130 | 130 | 130 | — | — | — | — | — | | | | | |
| | Compounding ratio(F/P)(mole ratio) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | | | | | |
| | 89% Phosphoric acid solution | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | | | | | |
| | Compounding amount of phosphoric acid (Pure content)(%/P) | 53.6 | 53.6 | 53.6 | 53.6 | 53.6 | 53.6 | 53.6 | 53.6 | 53.6 | 53.6 | 53.6 | | | | | |
| | Diethylene glycol | 108 | — | — | — | — | — | 108 | — | — | — | — | | | | | |
| | Ethylene glycol | — | 108 | — | — | — | — | — | 108 | — | — | — | | | | | |
| | Ethylene glycol Monomethyl ether | — | — | 108 | — | — | — | — | — | 108 | — | — | | | | | |
| | 1,4-Butanediol | — | — | — | 108 | — | — | — | — | — | 108 | — | | | | | |
| Cosolvent | 1,4-Dioxane | — | — | — | — | 108 | — | — | — | — | — | 108 | | | | | |
| | Dimethyl sulfoxide | — | — | — | — | — | 108 | — | — | — | — | — | | | | | |
| | Usage (%/P) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 60 | 60 | 50 | 50 | | | | | |
| | Reaction time (hour) | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 11 | 15 | 5 | 10 | | | | | |
| Properties | Monomeric phenol(%) | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | | | | | |
| | Dimeric phenol(%) | 4.4 | 5.3 | 4.8 | 5.2 | 6 | 7.9 | 7 | 7.5 | 7.2 | 6.5 | 13.7 | | | | | |
| | Number-average molecular weight(Mn) | 807 | 829 | 799 | 774 | 778 | 797 | 695 | 621 | 551 | 539 | 475 | | | | | |
| | Weight-average molecular weight(Mw) | 1014 | 996 | 1009 | 964 | 957 | 1049 | 814 | 735 | 657 | 641 | 581 | | | | | |
| | Degree of dispersion (Mw/Mn) | 1.26 | 1.2 | 1.26 | 1.25 | 1.23 | 1.32 | 1.17 | 1.18 | 1.19 | 1.19 | 1.22 | | | | | |
| | Melt viscosity (Pa·s/150°C) | 0.44 | 0.26 | 0.48 | 0.44 | 0.34 | 0.37 | 0.16 | 0.12 | 0.13 | 0.15 | 0.12 | | | | | |
| | Softening point(°C) | 96 | 93 | 96 | 94 | 90 | 91 | 82 | 73 | 81 | 80 | 74 | | | | | |
| Yield(%) | | 108 | 108 | 108 | 108 | 109 | 108 | 108 | 107 | 105 | 105 | 108 | | | | | |

<Examples 19 to 31>

Novolak resins were obtained in the same manner as in Example 1 except that the reaction conditions
5 were changed as shown in Table 3. The measured results are shown in Table 3. GPC charts of the novolak resins obtained in Examples 20, 21 and 26 are shown in Figs. 3, 4 and 5.

Table 3

| | | Example | | | | | | | | | | | | | |
|-------------------------------------|---|---------|-------|------|------|------|------|------|-------|------|------|------|------|------|--|
| | | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | |
| Reaction materials | Metacresol | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 90 | 80 | 80 | 80 | 80 | 40 | |
| | Paracresol | — | — | — | — | — | — | — | 10 | 20 | 20 | 20 | 40 | 60 | |
| | Raw material | — | — | — | — | — | — | — | — | — | — | 27.2 | 27.2 | 27.2 | |
| | 92% Paraform | — | — | — | — | — | — | — | — | — | — | — | — | — | |
| | 37% Formalin | 71.3 | 72.8 | 67.6 | 71.3 | 68.3 | 71.3 | 71.3 | 69.3 | 67.6 | 60.1 | — | — | — | |
| | Compounding ratio(F/P)(mole ratio) | 0.95 | 0.97 | 0.9 | 0.95 | 0.91 | 0.95 | 0.95 | 0.93 | 0.9 | 0.8 | 0.9 | 0.9 | 0.9 | |
| | 89% Phosphoric acid solution | 60 | 60 | 60 | 60 | 60 | 30 | 5.6 | 60 | 60 | 60 | 11.5 | 60 | 60 | |
| | Compounding amount of phosphoric acid (Pure content)(%/P) | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 26.7 | 5 | 53.4 | 53.4 | 53.4 | 10.2 | 53.4 | 53.4 | |
| | Ethylene glycol | 100 | 50 | — | — | — | 100 | 50 | 50 | — | 100 | — | 50 | — | |
| | Monobutyl ether | — | 50 | 100 | — | — | — | — | — | 100 | — | — | 50 | — | |
| Cosolvent | Ethylene glycol | — | — | — | 75 | — | — | — | — | — | — | — | — | — | |
| | Ethylene glycol | — | — | — | — | — | — | — | — | — | — | — | — | — | |
| | Monomethyl ether | — | — | — | — | — | — | — | — | — | — | — | — | — | |
| | 1,4-Dioxane | — | — | — | — | 100 | — | — | — | — | — | 100 | — | 100 | |
| Usage (%/P) | | 100 | 100 | 100 | 75 | 100 | 100 | 50 | 50 | 100 | 100 | 100 | 100 | 100 | |
| Reaction time (hour) | | 8 | 8 | 8 | 8 | 8 | 8 | 20 | 15 | 18 | 18 | 6 | 8 | 7 | |
| Monomeric phenol(%) | | 0.9 | 0.2 | 0.4 | 0.2 | 0.4 | 0.5 | 0.7 | 0.7 | 0.7 | 0.5 | 0.5 | 0.2 | N.D. | |
| Dimeric phenol(%) | | 2.4 | 0.7 | 1.7 | 0.7 | 1.2 | 3.1 | 4.9 | 4.2 | 3.3 | 8.5 | 4.9 | 7.5 | 5.6 | |
| Number-average molecular weight(Mn) | | 1572 | 2037 | 990 | 1612 | 1146 | 1338 | 1189 | 1378 | 1220 | 884 | 1154 | 887 | 833 | |
| Weight-average molecular weight(Mw) | | 10972 | 16893 | 1841 | 5178 | 2097 | 8286 | 6944 | 10762 | 3966 | 1490 | 8044 | 3522 | 2145 | |
| Degree of dispersion (Mw/Mn) | | 6.96 | 8.29 | 1.86 | 3.21 | 1.83 | 4.7 | 5.84 | 7.81 | 3.25 | 2.18 | 6.97 | 3.97 | 2.57 | |
| Softening point(°C) | | >200 | >200 | 152 | 184 | 153 | 169 | 164 | 176 | 151 | 132 | 167 | 148 | 140 | |
| Yield(%) | | 108 | 110 | 106 | 108 | 109 | 108 | 107 | 106 | 106 | 107 | 108 | 105 | 110 | |
| Alkali dissolving velocity (Å/sec) | | 297 | 265 | 6175 | 1097 | 5406 | 970 | 843 | 574 | 1083 | 4037 | 382 | 511 | <10 | |

<Examples 32 to 36>

Novolak resins were obtained in the same manner as in Example 1 except that the reaction conditions were changed as shown in Table 4. The measured results are shown in Table 4. A GPC chart of the novolak resin obtained in Example 36 is shown in Fig. 6.

10 <Example 37>

Into a pressure-resistant reaction vessel provided with a thermometer and a stirring device, 114 parts of bisphenol A, 13.1 parts of 92% paraformaldehyde, 68.4 parts of 89% phosphoric acid, and 57 parts of methanol were charged and raised to 110°C in a cloudy state (two-phase mixture) formed by stirring for mixing, and at the same temperature, a condensation reaction was conducted for one hour. At that time, the internal pressure (gage pressure) was 0.30 MPa.

Then, methyl isobutyl ketone was added to dissolve the condensate while stirring for mixing, the stirring for mixing was stopped, the content was moved into a separating flask and left standing to separate into a methyl isobutyl ketone solution layer (upper layer) and an aqueous phosphoric acid solution layer (lower layer). Then, the aqueous phosphoric acid solution layer was removed, the methyl isobutyl ketone solution was washed with water several times to remove phosphoric acid, the content was returned into the

reaction vessel, and the methyl isobutyl ketone was completely removed by vacuum distillation to obtain 116 parts of the novolak resin. The measured results are shown in Table 4.

5

<Example 38>

Novolak resin was obtained in the same manner as in Example 37 except that the reaction conditions were changed as shown in Table 4. The measured results are shown in Table 4.

10

Table 4

| | | Example | | | | | | |
|---------------------|---|---------|-------|-------|-------|-------|------|------|
| | | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
| Reaction materials | Bisphenol A | 228 | 228 | 228 | 228 | 228 | 114 | 114 |
| | 92% Paraform | — | — | — | — | 26.1 | 13.1 | 13.1 |
| | 37%Formalin | 64.9 | 64.9 | 64.9 | 64.9 | — | — | — |
| | Compounding ratio(F/P)(mole ratio) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| | 89% Phosphoric acid solution | 136.8 | 136.8 | 136.8 | 136.8 | 136.8 | 68.4 | 68.4 |
| | Compounding amount of phosphoric acid (Pure content)(%/P) | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 |
| | Ethylene glycol | 114 | — | — | — | — | — | — |
| | Monomethyl ether | — | 114 | — | — | — | — | — |
| | Ethylene glycol | — | — | — | — | — | — | — |
| | Diethylene glycol | — | — | 114 | — | — | — | — |
| Reaction conditions | 1,4-Dioxane | — | — | — | 114 | 114 | — | — |
| | Methanol | — | — | — | — | — | 57 | — |
| | Acetone | — | — | — | — | — | — | 57 |
| | Usage (%/P) | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| | Reaction time (hour) | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Internal pressure of reaction system (gage pressure)(MPa) | — | — | — | — | — | 0.3 | 0.2 |
| | Monomeric phenol(%) | 5.9 | 8.4 | 5.8 | 4.1 | 5.4 | 9.3 | 8.8 |
| | Dimeric phenol(%) | 16.8 | 24.1 | 19.1 | 24.1 | 25.5 | 22.1 | 25.5 |
| | Number-average molecular weight(Mn) | 832 | 688 | 767 | 805 | 672 | 722 | 753 |
| | Weight-average molecular weight(Mw) | 1500 | 1090 | 1460 | 1250 | 940 | 1105 | 1227 |
| Reaction properties | Degree of dispersion (Mw/Mn) | 1.81 | 1.59 | 1.91 | 1.55 | 1.4 | 1.53 | 1.63 |
| | Melt viscosity (Pa·s/180°C) | 3.33 | 0.6 | 1.91 | 1.92 | 1.07 | 1.49 | 0.59 |
| | Softening point(°C) | 133 | 122 | 130 | 129 | 124 | 129 | 121 |
| | Yield(%) | 104 | 104 | 104 | 105 | 105 | 103 | 105 |

<Examples 39 to 43>

Novolak resins were obtained in the same manner as in Example 37 except that the reaction conditions were changed as shown in Table 5 and the reaction temperature was changed to 150°C. The measured results are shown in Table 4. A GPC chart of the novolak resin at the completion of condensation obtained in Example 41 is shown in Fig. 7.

10 <Examples 44 to 50>

Novolak resins were obtained in the same manner as in Example 1 except that the reaction conditions were changed as shown in Table 5. The measured results are shown in Table 5. In Examples 49 and 50, polyoxyalkylene alkyl ether (NAROACTY HN100 produced by Sanyo Chemical Industries, Ltd.) was used as a surface active agent.

Table 5

| | | | | | | | | | | | | | | | | Example | | | | | | | | | | | | |
|---|---|--|--|--|--|--|--|--|--|--|--|--|--|--|--|-----------|-----------|-----------|-----------|-----------|-------|------|------|-------|-------|-------|-------|------|
| | | | | | | | | | | | | | | | | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | |
| Reaction conditions | Orthophenyl phenol | | | | | | | | | | | | | | | | 170.2 | 170.2 | 170.2 | 119.2 | 170.2 | 85.1 | — | — | — | 50 | 50 | 50 |
| | Ortho-tert-butylphenol | | | | | | | | | | | | | | | | — | — | — | — | — | — | 75.1 | — | — | — | — | — |
| | Orthocyclohexylphenol | | | | | | | | | | | | | | | | — | — | — | — | — | — | — | 88.1 | — | — | — | — |
| | 92% Paraform | | | | | | | | | | | | | | | | 26.1 | 26.1 | 26.1 | — | 19.6 | 13.1 | 13.1 | 13.1 | 5.7 | 5.7 | 5.7 | 5.7 |
| | 37%Formalin | | | | | | | | | | | | | | | | — | — | — | 45.5 | — | — | — | — | — | — | — | — |
| | Compounding ratio(F/P)(mole ratio) | | | | | | | | | | | | | | | | 0.8 | 0.8 | 0.8 | 0.8 | 0.6 | 0.8 | 0.8 | 0.8 | 0.6 | 0.6 | 0.6 | 0.6 |
| | 89% Phosphoric acid solution | | | | | | | | | | | | | | | | 102.1 | 102.1 | 102.1 | 71.5 | 102.1 | 51.1 | 45.1 | 52.9 | 30 | 30 | 30 | 30 |
| | Compounding amount of phosphoric acid (Pure content)(%/P) | | | | | | | | | | | | | | | | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 |
| | 1,4-Dioxane | | | | | | | | | | | | | | | | 85.1 | — | — | 59.6 | 85.1 | 42.6 | 75.1 | 44.1 | 25 | — | 25 | — |
| | Polyethylene glycol | | | | | | | | | | | | | | | | — | 85.1 | — | — | — | — | — | — | — | — | — | — |
| Cosolvent | Ethylene glycol | | | | | | | | | | | | | | | | — | — | 85.1 | — | — | — | — | — | — | — | — | — |
| | Monomethyl ether | | | | | | | | | | | | | | | | — | — | — | — | — | — | — | — | — | — | — | — |
| | Methanol | | | | | | | | | | | | | | | | — | — | — | — | — | — | — | — | — | 10 | — | 10 |
| | Usage (%/P) | | | | | | | | | | | | | | | | 50 | 50 | 50 | 50 | 50 | 50 | 100 | 50 | 50 | 20 | 50 | 20 |
| Surface active agent | | | | | | | | | | | | | | | | — | — | — | — | — | — | — | — | — | — | 2.5 | 2.5 | |
| Compounding amount of surface active agent (%/P) | | | | | | | | | | | | | | | | — | — | — | — | — | — | — | — | — | — | 5 | 5 | |
| Reaction time (hour) | | | | | | | | | | | | | | | | 10 | 10 | 10 | 20 | 10 | 24 | 24 | 24 | 2 | 2 | 2 | 2 | |
| Internal pressure of reaction system (gage pressure)(MPa) | | | | | | | | | | | | | | | | 0.15~0.20 | 0.07~0.10 | 0.10~0.14 | 0.36~0.39 | 0.16~0.20 | — | — | — | — | — | — | — | |
| Monomeric phenol(%) | | | | | | | | | | | | | | | | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | |
| Dimeric phenol(%) | | | | | | | | | | | | | | | | 17.1 | 17.5 | 14.7 | 21.4 | 49.1 | 35.8 | 19.5 | 31.5 | 78.9 | 95.4 | 86.7 | 95.7 | |
| Number-average molecular weight(Mn) | | | | | | | | | | | | | | | | 531 | 806 | 824 | 767 | 537 | 623 | 919 | 828 | 373 | 370 | 364 | 360 | |
| Weight-average molecular weight(Mw) | | | | | | | | | | | | | | | | 651 | 1151 | 1136 | 1048 | 636 | 819 | 1295 | 1095 | 441 | 407 | 415 | 392 | |
| Degree of dispersion(Mw/Mn) | | | | | | | | | | | | | | | | 1.23 | 1.43 | 1.38 | 1.37 | 1.18 | 1.31 | 1.41 | 1.32 | 1.18 | 1.1 | 1.14 | 1.09 | |
| Melt viscosity (Pa·s/180°C) | | | | | | | | | | | | | | | | 0.89 | 1.13 | 1.8 | 1.24 | 0.02 | 0.2 | 0.56 | 0.76 | <0.01 | <0.01 | <0.01 | <0.01 | |
| Softening point(°C) | | | | | | | | | | | | | | | | 101.8 | 103.9 | 106.5 | 104.1 | 69.3 | 87 | 99.2 | 98.8 | 47 | 52 | 49 | 52 | |
| Yield(%) | | | | | | | | | | | | | | | | 106 | 107 | 106 | 105 | 103 | 105 | 106 | 106 | 81 | 73 | 97 | 84 | |

<Examples 51 to 56>

Novolak resins were obtained in the same manner as in Example 1 except that the reaction conditions were changed as shown in Table 6. The measured results are shown in Table 6. A GPC chart of the novolak resin at the completion of condensation obtained in Example 55 is shown in Fig. 8. In Examples 54 to 56, polyoxyalkylene alkylether (NAROACTY HN100 produced by Sanyo Chemical Industries, Ltd.) was used as a surface active agent.

Table 6

| | | Example | | | | | | |
|---------------------|---|---------|-------|-------|-------|-------|-------|--|
| | | 51 | 52 | 53 | 54 | 55 | 56 | |
| Reaction conditions | Raw material | | | | | | | |
| | Para-tert-butylphenol | 50 | 50 | — | 50 | 50 | 50 | |
| | Paraphenyl phenol | — | — | 50 | — | — | — | |
| | 92% Paraform | 6.5 | 6.5 | 5.3 | 5.4 | 6 | 6.5 | |
| | 37%Formalin | — | — | — | — | — | — | |
| | Compounding ratio(F/P)(mole ratio) | 0.6 | 0.6 | 0.55 | 0.5 | 0.55 | 0.6 | |
| | Catalyst | 30 | 30 | 30 | 30 | 30 | 30 | |
| | 89% Phosphoric acid solution | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | |
| | Compounding amount of phosphoric acid (Pure content)(%/P) | — | — | 12.5 | 12.5 | 12.5 | 12.5 | |
| | 1,4-Dioxane | 12.5 | — | — | — | — | — | |
| Cosolvent | glycerine | — | 2.5 | — | — | — | — | |
| | Methanol | 25 | 5 | 25 | 25 | 25 | 25 | |
| | Usage (%/P) | — | — | — | 2.5 | 2.5 | 2.5 | |
| | Surface active agent | — | — | — | 5 | 5 | 5 | |
| | Compounding amount of surface active agent (%/P) | 4 | 5 | 7 | 5 | 2 | 2 | |
| Properties | Reaction time (hour) | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | |
| | Monomeric phenol(%) | 76.9 | 70.9 | 65 | 77.6 | 73.6 | 68.1 | |
| | Dimeric phenol(%) | 490 | 509 | 383 | 491 | 500 | 509 | |
| | Number-average molecular weight(Mn) | 535 | 570 | 460 | 525 | 550 | 580 | |
| | Weight-average molecular weight(Mw) | 1.09 | 1.12 | 1.2 | 1.07 | 1.1 | 1.14 | |
| | Degree of dispersion (Mw/Mn) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | |
| | Melt viscosity (Pa·s/180°C) | 69 | 73 | 40 | 68 | 71 | 75 | |
| | Softening point(°C) | 93 | 93 | 90 | 92 | 103 | 98 | |
| | Yield(%) | | | | | | | |

<Example 57>

Novolak resin was obtained in the same manner as in Example 1 except that the reaction conditions were changed as shown in Table 7. The measured results are shown in Table 7.

<Examples 58 to 65>

Novolak resins were obtained in the same manner as in Example 37 except that the reaction conditions were changed as shown in Table 7 and the reaction temperature was changed to 130°C. The measured results are shown in Table 7. A GPC chart of the novolak resin at the completion of condensation obtained in Example 61 is shown in Fig. 9.

15

Table 7

| | | Example | | | | | | | | | |
|--------------|---|---------|------|---------------|---------------|---------------|------|------|---------------|---------------|--|
| | | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | |
| Raw material | Para-tert-butylphenol | 75.1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | — | |
| | Paraphenyl phenol | | — | — | — | — | — | — | — | 100 | |
| | 92% Paraform | 13.1 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 19.6 | 15.3 | |
| | 37%Formalin | — | — | — | — | — | — | — | — | — | |
| | Compounding ratio(F/P)(mole ratio) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.8 | |
| | 89% Phosphoric acid solution | 45.1 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | |
| | Compounding amount of phosphoric acid (Pure content)(%/P) | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | 53.4 | |
| | 1,4-Dioxane | 37.6 | 50 | — | — | — | — | — | — | 50 | |
| | Methanol | — | — | 50 | — | — | — | — | — | — | |
| | n-Propanol | — | — | — | 50 | — | — | — | 50 | — | |
| Cosolvent | n-Butanol | — | — | — | — | 50 | — | — | — | — | |
| | Ethylene glycol | — | — | — | — | — | — | — | — | — | |
| | Monomethyl ether | — | — | — | — | — | 50 | — | — | — | |
| | Ethylene glycol | — | — | — | — | — | — | 50 | 50 | — | |
| | Usage (%/P) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | |
| | Internal pressure of reaction system (gage pressure)(MPa) | — | 0.12 | 0.42~ 0.70 | 0.11~ 0.20 | 0.10~ 0.13 | 0.03 | 0.12 | 0.20~ 0.23 | 0.15~ 0.20 | |
| | Reaction time (hour) | 24 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |
| | Monomeric phenol(%) | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | |
| | Dimeric phenol(%) | 19.5 | 19.8 | 9.4 | 10.0 | 11.7 | 15.2 | 16.3 | 2.2 | 13.4 | |
| | Number-average molecular weight(Mn) | 774 | 774 | 971 | 711 | 840 | 857 | 871 | 1114 | 845 | |
| Properties | Weight-average molecular weight(Mw) | 987 | 973 | 1343 | 861 | 1062 | 1235 | 1148 | 1484 | 1367 | |
| | Degree of dispersion (Mw/Mn) | 1.27 | 1.26 | 1.38 | 1.21 | 1.26 | 1.44 | 1.32 | 1.33 | 1.62 | |
| | Melt viscosity (Pa·s/180°C) | 0.08 | 0.06 | 0.6 | 0.33 | 0.26 | 0.18 | 0.21 | >1.0 | 0.52 | |
| | Softening point(°C) | 114 | 113 | 135 | 129 | 126 | 122 | 123 | 156 | 132 | |
| | Yield(%) | 105 | 105 | 105 | 106 | 107 | 105 | 105 | 104 | 106 | |

<Comparative Example 1>

Into a reaction vessel provided with a thermometer, a stirring device and a condenser, 193 parts of phenol, 142 parts of 37% formalin and 0.97 parts of oxalic acid were charged and gradually raised to a reflux temperature (98 to 102°C) and, at the same temperature, a condensation reaction was conducted for six hours, and concentration was conducted under a reduced pressure to obtain 199g of a novolak resin. The measured results are shown in Table 8. A GPC chart of the obtained novolak resin is shown in Fig. 10.

15 <Comparative Examples 2 to 9>

Novolak resins were obtained in the same manner as in Comparative Example 1 except that the reaction conditions were changed as shown in Table 8. The measured results are shown in Table 8. A GPC chart of the novolak resin obtained in Comparative Example 6 is shown in Fig. 11, and GPC charts of the novolak resins at the completion of condensation obtained in Comparative Examples 8, 9 are shown in Figs. 12, 13.

Table 8

| | | Comparative Example | | | | | | | | |
|---------------------|-------------------------------------|---------------------|-------|------|------|------|------|------|-------|-------|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Reaction materials | Phenol | 193 | 193 | 193 | — | — | — | — | — | — |
| | Orthocresol | — | — | — | 216 | — | — | — | — | — |
| | Metacresol | — | — | — | — | 80 | — | — | — | — |
| | Paracresol | — | — | — | — | 20 | — | — | — | — |
| | Bisphenol A | — | — | — | — | — | 228 | 228 | — | — |
| | Orthophenylphenol | — | — | — | — | — | — | — | 85.1 | — |
| | Para-tert-butylphenol | — | — | — | — | — | — | — | — | 50 |
| | 92% Paraform | — | — | — | — | — | — | — | 13.1 | — |
| | 47% Formalin | — | — | — | 102 | — | 51.1 | 41.5 | — | — |
| | 37% Formalin | 142 | 130 | 83 | — | 60.1 | — | — | — | 14.9 |
| Reaction conditions | Compounding ratio (F/P)(mole ratio) | 0.85 | 0.78 | 0.5 | 0.8 | 0.8 | 0.8 | 0.65 | 0.8 | 0.55 |
| | Catalyst | 0.97 | 0.97 | 0.97 | 1.08 | 0.2 | 2.28 | 2.28 | 0.85 | 0.5 |
| | Ethylene glycol | — | — | — | — | — | — | — | — | 5 |
| | Usage (%/P) | — | — | — | — | — | — | — | — | 10 |
| Properties | Reaction time (hour) | 6 | 6 | 8 | 10.5 | 6 | 2.5 | 3 | 20 | 1 |
| | Monomeric phenol(%) | 2.6 | 1.2 | 0.5 | 1.3 | 0.55 | 14.2 | 20.4 | N.D. | N.D. |
| | Dimeric phenol(%) | 9.4 | 11.2 | 26.4 | 17.6 | 9.95 | 10.1 | 14.9 | 14.4 | 71 |
| | Number-average molecular weight(Mn) | 888 | 673 | 432 | 589 | 763 | 745 | 566 | 645 | 511 |
| | Weight-average molecular weight(Mw) | 4606 | 2165 | 651 | 878 | 3497 | 2900 | 1390 | 910 | 575 |
| | Degree of dispersion (Mw/Mn) | 5.19 | 3.2 | 1.5 | 1.49 | 4.58 | 3.89 | 2.45 | 1.41 | 1.13 |
| | Melt viscosity (Pa·s/150°C) | 13.0 | 4.2 | 0.12 | 0.13 | — | 4.16 | 0.19 | 3.15 | <0.01 |
| | Softening point(°C) | 115 | 106.9 | 68.4 | 78 | 136 | 131 | 116 | 109.4 | 74 |
| | Yield(%) | 103 | 97 | 75 | 106 | 88 | 104 | 103 | 79 | 29 |

<Example 66>

In a reaction vessel provided with a thermometer, a stirring device and a condenser, novolak resin was obtained (a monomeric phenol: N.D., a dimeric phenol: 10.0%, a number-average molecular weight (Mn): 681, a weight-average molecular weight (Mw): 826, a degree of dispersion (Mw/Mn): 1.21) in the same manner as in Example 14 except that the compounding ratio (F/P) in Example 14 was changed from 0.75 to 0.80.

The novolak resin 50 parts (hydroxyl equivalent: 117g/eq, equivalent weight 0.43), epichlorohydrin 296 parts (equivalent weight 3.2) and n-butanol 100 parts were charged and stirred for mixing so as to prepare a homogeneous solution. Then, 39 parts of 48% sodium hydroxide solution (equivalent weight 0.47) was dripped for 30 minutes. After the dripping was completed, the reaction was further conducted at 70°C for 30 minutes. After cooling to 40°C or below, the solution was left standing still to separate into a water layer (upper layer) and an n-butanol solution layer (lower layer).

Then, the n-butanol solution obtained by separating as described above was moved into a separating flask and washed by water until the washing water became neutral. The solution was returned to the reaction vessel, and the n-butanol and the epichlorohydrin were removed by vacuum distillation to obtain epoxy resin. The measured results are shown in Table 9.

<Comparative Example 10>

Epoxy resin was obtained in the same manner as in Example 66 except that the novolak resin was changed to the novolak resin synthesized in Comparative

5 Example 4. The measured results are shown in Table 9.

Table 9

| | Example 66 | Comp.Ex. 10 |
|-------------------------------------|------------|-------------|
| Monomeric phenol+dimeric phenol (%) | 10.7 | 18 |
| Melt viscosity (Pa·s/150°C) | 0.054 | 0.096 |
| Epoxy equivalent (g/eq) | 207 | 212 |
| Softening point (°C) | 49 | 51 |

<Example 67, Comparative Examples 11, 12>

10 [Example 67]

Into a reaction vessel provided with a thermometer, a stirring device, a condenser and a dropping funnel, 60 parts of the novolak resin (hydroxyl equivalent 119g/eq) obtained in Example 34,
15 349.7 parts of epichlorohydrin, 120 parts of n-butanol were charged, and a temperature was raised to 70°C to completely dissolve the novolak resin. Then, after cooling to 50°C, 46.2 parts of 48% sodium hydroxide solution was dripped, and the temperature was
20 gradually raised so that the inner temperature became 70°C when the dripping was completed. When the dripping was completed, an epoxidation reaction was conducted at 70°C for 0.5 hour, and the reaction was stopped. After the inner temperature was cooled to
25 room temperature, methyl isobutyl ketone was added while stirring for mixing to dissolve the content.

Then, the content was moved into a separating flask and left standing to separate into a methyl isobutyl ketone solution layer (upper layer) and an

aqueous sodium hydroxide solution layer (lower layer).
Then, the aqueous sodium hydroxide solution layer was
removed, the methyl isobutyl ketone solution was
washed with water several times to remove sodium
5 hydroxide, the content was returned into the reaction
solution, and methyl isobutyl ketone and excess
epichlorohydrin were removed completely by vacuum
distillation to obtain 85 parts of the epoxy resin.
The measured results are shown in Table 10.

10

[Comparative Examples 11, 12]

Epoxy resins were obtained in the same manner as
in Example 67 except that the novolak resin was
changed to the novolak resin (hydroxyl equivalent
15 119g/eq) obtained in Comparative Example 6 and the
novolak resin (hydroxyl equivalent 119g/eq) obtained
in Comparative Example 7. The measured results are
shown in Table 10.

20 [Rheometer measurement]

The obtained epoxy resin 20g and phenol novolak
(a product of Asahi Organic Chemicals Industry Co.,
Ltd., Mw; 959, Mn; 611) 10g as a curing agent were
mixed by heating to melt in an aluminum cup. Then,
25 the mixture 10g and 2-methyl imidazole (a curing
accelerator) 0.05g were mixed by pulverizing by a
coffee mill to prepare a mixture, the prepared mixture
6g and Crystalite A-1 (product of TATSUMORI LTD.) 14g
as an inorganic filler were mixed by pulverizing by
30 the coffee mill for 30 seconds to prepare a sample.

Then, the sample 18g was charged into a 50×70×2.5-mm mold heated to 180°C and formed into a 70×50×2.5-mm compact under compression (8.4×10^6 Pa (86 kg/cm²) by a 20-t press machine, and it was cut into a size of 12×50×2.5 mm by a LUXO® to prepare a test piece. Then, the test piece was sandwiched by a jig for tension test to measure the viscoelasticity of the compact by a torsion method using an ARES (Advance Rheometric Expansion System) viscoelasticity measuring system of Rheometric Scientific F. E. Inc. The measuring conditions were a distortion of 0.01%, a frequency of 10 Hz, a tensile load of 15g, a measured temperature range of 25 to 300°C, a temperature rising velocity of 10°C/minute, and the number of measurements 1/30 seconds.

It is seen from the results of measurement by the rheometer of Fig. 14 that, when the behaviors of $\tan \delta$ at the time of raising a temperature were compared, the test piece prepared from the epoxy resin of Example 67 had a Tg value (crosslinking density) equivalent to that of the test piece prepared from the epoxy resin of Comparative Example 11 having a large weight-average molecular weight and higher than that of the test piece prepared from the epoxy resin of Comparative Example 12 having the same weight-average molecular weight. Thus, it was confirmed that the cured matter of the epoxy resin produced of the novolak resin obtained by the present invention had a crosslinking density higher than that of the epoxy resin produced by Comparative Example 12 and

equivalent to that of the epoxy resin produced by Comparative Example 11. But, the melt viscosity was half or less of that of the epoxy resin produced by Comparative Example 11 but higher than that of the epoxy resin produced by Comparative Example 12. In other words, it was confirmed that the content and a degree of dispersion of a monomeric phenol (unreacted bisphenol A) had an effect on the crosslinking density and melt viscosity.

Table 10

| | Example 67 | Comp. Ex. 11 | Comp. Ex. 12 |
|-----------------------------|------------|--------------|--------------|
| Epoxy equivalent (g/eq) | 225.7 | 214.5 | 232.9 |
| Melt viscosity (Pa·s/180°C) | 0.24 | 0.60 | 0.08 |
| Softening point (°C) | 82.3 | 83.9 | 68.3 |
| Tg(°C) | 205 | 205 | 170 |

INDUSTRIAL APPLICABILITY

According to the process for production of the present invention, the phenolic novolak with the contents and the degree of dispersion of the monomeric phenol and a dimeric phenol controlled can be obtained in high yield, and the production cost can be reduced substantially.

The reaction time can be reduced and the yield can be improved by additionally having a surface active agent during the heterogeneous reaction step, and the yield can be improved.

By conducting the heterogeneous reaction step under pressure of 0.03 to 1.50 MPa, the reaction time can be reduced, and a low-boiling solvent such as methanol can be used as a reaction cosolvent.